Background—Left ventricular hypertrophy (LVH) represents an independent risk factor in patients with essential hypertension. Because reversal of LVH may be associated with an improvement of prognosis, the influence of new antihypertensive compounds, such as angiotensin II AT<sub>1</sub> receptor antagonists, on LVH should be determined.

Methods and Results—In a randomized, double-blind trial, 69 predominantly previously untreated hypertensive patients with echocardiographically proven LVH, i.e., left ventricular mass index (LVMI) >134 g/m<sup>2</sup> in men and >110 g/m<sup>2</sup> in women and/or end-diastolic septal thickness >12 mm, received either the angiotensin II antagonist valsartan or atenolol for 8 months. Echocardiographic data of 58 patients were available. After 8 months of valsartan treatment (n=29), LVMI decreased from 127±23 to 106±25 g/m<sup>2</sup> (ratio [R]=0.83; 95% CI, 0.79 to 0.87; P<0.0001 versus baseline). Under atenolol (n=29), LVMI decreased to a smaller extent, from 127±25 to 117±27 g/m<sup>2</sup> (R=0.92; 95% CI, 0.86 to 0.98; P=0.0082 versus baseline). The mean reduction of LVMI came to 21 g/m<sup>2</sup> under valsartan and only to 10 g/m<sup>2</sup> under atenolol (R=0.91; 90% CI, 0.85 to 0.97 versus atenolol). Baseline mean blood pressure values were determined to be 163±12/101±6 mm Hg before treatment with valsartan and 160±14/103±6 mm Hg before atenolol treatment. After 8 months of treatment, mean blood pressure decreased to 146±13/90±7 mm Hg with valsartan and to 147±18/90±7 mm Hg with atenolol. Nine patients in the valsartan group and 8 patients in the atenolol group required additional medication with hydrochlorothiazide.

Conclusions—Antihypertensive treatment with the angiotensin II antagonist valsartan for 8 months produced a significant regression of LVH in predominantly previously untreated patients with essential hypertension. The drug may be safely administered in this subset of hypertensive patients; however, the long-term benefit in terms of risk reduction has still to be evaluated in further trials. (Circulation. 1998;98:2037-2042.)

Key Words: hypertension ■ hypertrophy ■ ventricles ■ angiotensin
suggest a considerable effect of this class of drugs on myocardial hypertrophy and fibrosis.\textsuperscript{13,16}

The antihypertensive efficacy of the selective Ang II antagonist valsartan\textsuperscript{17} in essential hypertensive patients was shown earlier.\textsuperscript{18} We investigated the influence of 8 months of antihypertensive treatment with this Ang II antagonist on LVH versus the \(\beta\)-adrenergic receptor antagonist atenolol. \(\beta\)-Adrenergic receptor antagonists are included as first-line treatment in the recommendations of most national and international committees for the treatment of high blood pressure. Atenolol has recently been shown to be at least equally tolerable and to ensure blood pressure control comparable to that with enalapril, hydrochlorothiazide (HCTZ), and nitrendipine.\textsuperscript{19} We enrolled predominantly untreated patients or those who had been treated (1) for previous 12 months or (2) with diuretics only were screened. Pretreatment with valsartan 80 mg/d or atenolol 50 mg/d for the following 4 weeks. If blood pressure was not adequately controlled, ie, sitting diastolic blood pressure still exceeded 95 mm Hg. After 3 months, the second echocardiogram was performed; regular visits were then at 8-week intervals. The final visit and third echocardiogram were performed after 8 months of double-blind treatment.

**Methods**

**Patients and Study Design**

The trial followed a randomized, double-blind, actively controlled, parallel-group design.\textsuperscript{20} The study protocol was approved by the ethics committee of the University Hospital in Frankfurt, and all study participants gave written informed consent before participation in the trial. Patients were recruited and treated by 14 general practitioners, whereas echocardiographic readings and analyses were performed at 1 central laboratory (P.K.).

One hundred seventeen previously untreated, white, hypertensive patients or those who had been treated (1) for \(<=4\) weeks during the previous 12 months or (2) with diuretics only were screened. Secondary forms of hypertension were excluded. Pretreatment with diuretics was considered acceptable, because their effect on left ventricular mass and especially wall thickness parameters has been shown to be negligible.\textsuperscript{21} Normal renal and liver function tests as well as blood counts were confirmed in 1 central laboratory.

The inclusion criterion was a diastolic blood pressure between 95 and 115 mm Hg and systolic blood pressure between 150 and 180 mm Hg determined after a single-blind, 3-week placebo run-in period. All blood pressure measurements were performed in duplicate with a standard cuff sphygmomanometer after 10 minutes in the sitting position. During the run-in period, the presence of LVH was established by echocardiography and defined as left ventricular mass index (LVMI) >134 g/m\(^2\) body surface area for men and >110 g/m\(^2\) for women and/or septal thickness >12 mm at end diastole.\textsuperscript{22} Randomized patients received, in a double-blind manner, either valsartan 80 mg/d or atenolol 50 mg/d for the following 4 weeks. If blood pressure was not adequately controlled, ie, sitting diastolic blood pressure measured in the morning before drug intake >95 mm Hg, the dose of both drugs was doubled. After an additional 4 weeks, HCTZ could be added in those patients in whom diastolic blood pressure still exceeded 95 mm Hg. After 3 months, the second echocardiogram was performed; regular visits were then at 8-week intervals. The final visit and third echocardiogram were performed after 8 months of double-blind treatment.

**Echocardiography**

All echocardiographic recordings were performed by 1 experienced investigator using a Hewlett Packard Sonos 1000 system with a 2.5-MHz transducer according to recommendations of the American Society of Echocardiography.\textsuperscript{23} M-mode recordings were guided by 2-dimensional views. LVMI was calculated according to the formula of Devereux et al.\textsuperscript{24} Left ventricular end-diastolic and end-systolic volumes were determined by 2-dimensional echocardiography, and left ventricular ejection and fractional shortening were calculated with standard formulas. Pulsed-wave Doppler recordings of mitral flow velocity were performed to calculate the areas under the velocity/time curves \(E\) and \(fA\).

Values from at least 3 beats were measured and averaged, and intraobserver variability was determined to be 6.8%, 6.2%, 3.8%, and 13% for end-diastolic septal thickness, end-diastolic posterior wall thickness, left ventricular internal diameter, and \(V_{\max E}/V_{\max A}\), respectively.\textsuperscript{24}

**Statistical Analysis**

For primary efficacy analysis, baseline and final LVMI values were compared within treatment groups. To detect a clinically relevant change of \(\geq 15\%\) with 80% power, 26 patients were required in each treatment group, assuming a coefficient of variation of 29% and using Student’s \(t\) test on logarithmically transformed data. The level of significance was set to 5%. To compare the change in LVMI between groups, the 90% CI of the 2 ratios could be calculated with a precision of \(\pm 13\%\).

For the intention-to-treat analysis, all randomized patients having at least 1 postbaseline echocardiogram were included. The primary efficacy variable LVMI and secondary variables were analyzed after logarithmic transformation of the data by the paired \(t\) test (SAS), and the corresponding 95% CIs were calculated.

Between-treatment differences were analyzed by ANCOVA, and 95% CIs were derived. Data are given as mean\(\pm SD\); if appropriate, the median value is quoted.

A correlation analysis (Kendall) was performed between percent reduction in systolic and diastolic blood pressures, respectively, and change in LVMI. Kendall correlation coefficients (\(\tau\)) and corresponding \(P\) values are given.

**Results**

**Patients**

One hundred seven patients underwent a baseline echocardiogram; 69 met the inclusion criteria (Table 1). The known duration of hypertension was maximally 8 years (median, 17 months). Two patients were pretreated with diuretics, and 11

<p>| TABLE 2. Number of Patients With Concomitant Chronic Diseases and Number of Patients Receiving Chronic Concomitant Medication |
|---------------------------------------------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th><strong>Valsartan</strong>, n</th>
<th><strong>Atenolol</strong>, n</th>
<th><strong>Concomitant Medication</strong>, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthrosis, osteoarthritis</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Diabetes type II</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Thyroid disease</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Hyperuricemia</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Total n=69 randomized patients.
patients had received other blood pressure–lowering drugs for <4 weeks in the 12 months before the study. Concomitant diagnoses and medications are given in Table 2. In addition, 9 patients received acetylsalicylic acid and paracetamol for relief of common cold symptoms.

Three patients in each treatment group discontinued the study because of adverse events: under valsartan, 1 female patient developed a probably drug-induced bilateral dermatitis of the breast, 1 patient had a subarachnoid hemorrhage, and in 1 patient a brain tumor was diagnosed. Under atenolol, 2 patients experienced angina and 1 patient dyspnea, the latter possibly associated with atenolol. Safety blood chemistry parameters revealed no variations in the mean and median values, especially for serum creatinine and urea, as well as blood lipid profiles, with the exception of 1 patient receiving atenolol 100 mg/d plus HCTZ, in whom a clinically relevant increase of serum uric acid, creatinine, and urea occurred.

Fifty-eight patients (n=29 in each treatment group) were evaluable for the intention-to-treat analysis of LVH; echocardiographic data and blood pressure values for these patients are presented.

**Blood Pressure Control**

In the valsartan treatment group, a dose increment to 160 mg/d was required in 14 patients, and 9 patients required additional medication with HCTZ. In the atenolol group, 16 patients received 100 mg/d, and in 8 patients, addition of HCTZ was necessary to achieve a satisfactory blood pressure control.

After 8 months of valsartan treatment, systolic blood pressure decreased from 163±12 to 146±13 mm Hg (mean, –17 mm Hg; 95% CI, –21 to 13 mm Hg; P<0.0001), diastolic blood pressure decreased from 101±6 to 90±7 mm Hg (mean, –11 mm Hg; 95% CI, –14 to 8 mm Hg; P<0.0001). Treatment with atenolol resulted in a decrease of systolic blood pressure from 160±14 to 147±18 mm Hg (mean, –13 mm Hg; 95% CI, –18 to 7 mm Hg; P<0.0001), and diastolic blood pressure was reduced from 103±6 to 90±7 mm Hg (mean, –12 mm Hg; 95% CI, –15 to 9 mm Hg; P<0.0001).

Heart rate remained almost unchanged under valsartan treatment at 76 bpm (median value) before treatment and 73 bpm after 8 months of treatment, whereas under atenolol, an expected marked decrease from 76 to 64 bpm was observed.

**Echocardiographic Data**

After 3 months of valsartan therapy, LVMI decreased slightly, from 127±23 to 119±23 g/m², whereas a significant decrease could be observed after 8 months to 106±25 g/m².

**TABLE 3. M-Mode and 2-Dimensional Echocardiographic Parameters (mean±SD) Obtained During the Study (Intention-to-Treat Analysis, n=29 in Each Treatment Group)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Valsartan</th>
<th>Atenolol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>8 mo, R (95% CI)</td>
</tr>
<tr>
<td><strong>LVMI, g/m²</strong></td>
<td>127±23</td>
<td>106±25‡†‡†</td>
</tr>
<tr>
<td></td>
<td>0.83 (0.79–0.87)</td>
<td>0.92 (0.86–0.98)</td>
</tr>
<tr>
<td><strong>PWTd, mm</strong></td>
<td>13.6±0.7</td>
<td>12.4±1.0†‡</td>
</tr>
<tr>
<td></td>
<td>0.91 (0.88–0.93)</td>
<td>0.95 (0.92–0.98)</td>
</tr>
<tr>
<td><strong>IVSd, mm</strong></td>
<td>13.7±1.2</td>
<td>12.2±1.1‡‡</td>
</tr>
<tr>
<td></td>
<td>0.89 (0.87–0.92)</td>
<td>0.93 (0.91–0.95)</td>
</tr>
<tr>
<td><strong>LVIDd, mm</strong></td>
<td>47.24±5.13</td>
<td>46.22±5.54</td>
</tr>
<tr>
<td><strong>LVIDs, mm</strong></td>
<td>29.07±4.83</td>
<td>28.46±4.15</td>
</tr>
<tr>
<td><strong>FS, %</strong></td>
<td>39±8</td>
<td>38±6</td>
</tr>
<tr>
<td></td>
<td>1.01 (0.92–1.10)</td>
<td>1.02 (0.94–1.12)</td>
</tr>
<tr>
<td><strong>LVEDV, mL</strong></td>
<td>91.00±27.38</td>
<td>94.97±21.94</td>
</tr>
<tr>
<td><strong>LVESV, mL</strong></td>
<td>32.31±15.67</td>
<td>34.07±11.59</td>
</tr>
<tr>
<td><strong>EF, %</strong></td>
<td>65±10</td>
<td>65±7</td>
</tr>
<tr>
<td></td>
<td>1.00 (0.94–1.07)</td>
<td>1.02 (0.95–1.10)</td>
</tr>
</tbody>
</table>

PWTd indicates end-diastolic posterior wall thickness; IVSd, end-diastolic septal wall thickness; LVIDd, left ventricular end-diastolic diameter; LVIDs, left ventricular end-systolic diameter; FS, fractional shortening; LVEDV, left ventricular end-diastolic volume; LVESV, left ventricular end-systolic volume; and EF, ejection fraction.

*P<0.01 vs baseline; †P<0.005 vs baseline; ‡P<0.0001 vs baseline.
TABLE 4. Doppler Echocardiographic Parameters (mean±SD) Obtained During the Study (Intent-to-Treat Analysis, n=29 in Each Treatment Group)  

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline</th>
<th>8 mo, R (95% CI)</th>
<th>Baseline</th>
<th>8 mo, R (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{\text{max}E} ), cm/s</td>
<td>75.30±18.27</td>
<td>70.14±12.42</td>
<td>73.57±16.05</td>
<td>78.25±17.69</td>
</tr>
<tr>
<td>( V_{\text{max}A} ), cm/s</td>
<td>82.64±19.35</td>
<td>78.07±16.48</td>
<td>81.57±17.27</td>
<td>75.48±12.21</td>
</tr>
<tr>
<td>( fE ), cm</td>
<td>10.76±3.02</td>
<td>11.61±2.33</td>
<td>11.68±3.39</td>
<td>12.57±2.96</td>
</tr>
<tr>
<td>( fA ), cm</td>
<td>10.66±2.98</td>
<td>10.46±2.60</td>
<td>10.55±2.53</td>
<td>9.71±2.20</td>
</tr>
<tr>
<td>( fE/fA )</td>
<td>1.06±0.33</td>
<td>1.16±0.29</td>
<td>1.14±0.35</td>
<td>1.31±0.25</td>
</tr>
</tbody>
</table>

\( V_{\text{max}E} \) indicates maximal velocity of early diastolic filling phase; \( V_{\text{max}A} \), maximal velocity of late diastolic filling phase; \( fE \), time/velocity integral of early diastolic filling phase; \( fA \), time/velocity integral of late diastolic filling phase; and \( fE/fA \), ratio of the integrals.

*P<0.01 vs baseline.

Table 5. Correlation Coefficients Between Percent Reduction of Blood Pressure and Decrease in LVMI (Kendall Correlation Coefficient, \( \tau \))  

<table>
<thead>
<tr>
<th></th>
<th>Valsartan, ( \tau ) (( P ))</th>
<th>Atenolol, ( \tau ) (( P ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>% reduction in diastolic BP vs % decrease in LVMI</td>
<td>0.195 (0.14)</td>
<td>-0.193 (0.14)</td>
</tr>
<tr>
<td>% reduction in systolic BP vs % decrease in LVMI</td>
<td>0.197 (0.13)</td>
<td>-0.032 (0.81)</td>
</tr>
</tbody>
</table>

BP indicates blood pressure.

In the atenolol group, LVMI decreased from 127±25 to 119±23 g/m² during the first 3 months; after 8 months, LVMI was determined to be 117±27 g/m² (\( R=0.92; 95\% \) CI, 0.86 to 0.98; \( P=0.0082 \) vs baseline; Figure 1). Covariate analyses revealed no influence of sex and age on treatment effects.

The mean reduction of LVMI was 21 g/m² under valsartan and 10 g/m² under atenolol (\( R=0.91; 90\% \) CI, 0.85 to 0.97 versus atenolol), suggesting a tendency toward a more pronounced treatment effect with valsartan.

Septal and posterior wall thicknesses were reduced by both drugs, valsartan being slightly more effective (Table 3). Left ventricular internal diameters and volumes and their derived parameters ejection fraction and fractional shortening remained almost constant (Table 3).

No relevant changes were observed for Doppler echocardiographic parameters (Table 4); the ratio \( fE/fA \) showed a small but significant increase after atenolol treatment (\( R=1.18; 95\% \) CI, 1.05 to 1.33; \( P<0.01 \) vs baseline).

No significant correlation could be found between the changes in blood pressure and in LVMI (Table 5) for either valsartan or atenolol treatment.

Discussion

The prevalence of LVH has recently been estimated to be 62% in essential hypertensive patients with a diastolic blood pressure between 100 and 115 mm Hg, which is in accordance with our screening results. In contrast to 3 previous studies in patients with LVH who were given the Ang II antagonist losartan, we observed a significant reduction of LVMI, from 139 to 133 g/m²; in contrast, ramipril produced a significant reduction, from 136 to 117 g/m². The reduction of 19 g/m² obtained with the ACE inhibitor appears to be comparable to our results with an AT₁ antagonist.

We found no significant correlation between blood pressure reduction and decrease in left ventricular mass, possibly because of the sample size and the large variability of findings. However, there was a trend for a positive correlation for valsartan, but not for atenolol. In 206 essential hypertensive patients receiving lisinopril and additional HCTZ, no correlation could be demonstrated between change in clinic sitting blood pressure and change in LVMI, whereas a close correlation was found between decrease in average 24-hour ambulatory blood pressure values and reduction in LVMI.

In renovascular hypertensive rats, Zierhut et al observed a significant decrease of LVMI after 12 weeks of treatment with valsartan, comparable to the effect induced by an ACE inhibitor. Treatment with the Ang II antagonist TCV-116 prevented the development of LVH in the spontaneously hypertensive rat model by reducing left ventricular wall thickness and weight and also interstitial fibrosis.

It has been suggested that AT₁ antagonists, like ACE inhibitors, possess a pharmacological effect beyond blood pressure reduction, in which blockade of the AT₁ receptor may lead to an attenuation of the growth-promoting actions of Ang II.
However, little is known about the presence and role of the AT_2 receptor subtype (and other subtypes) in patients with LVH. Liu and coworkers showed, in rats after myocardial infarction, that a considerable share of the beneficial effects of an Ang II AT_1 receptor antagonist could be attenuated by additional treatment with an AT_2 antagonist. These findings indicate that stimulation of the AT_2 receptor plays an important role in the mechanism of action of selective AT_1 receptor antagonists. Irrespective of the mechanism of action, the ELITE trial demonstrated that the Ang II antagonist losartan is at least as effective as an ACE inhibitor with regard to prevention of heart failure–related hospital admissions and reduction of total mortality.

Some aspects of our study may be considered to be shortcomings. First, treatment duration was restricted to 8 months. Liebson and coworkers described an additional decrease of left ventricular mass after 12 months of treatment with different antihypertensive drug classes.

The addition of HCTZ was required equally in both our treatment groups, and a beneficial influence of this diuretic on LVM cannot be ruled out. According to Liebson et al and others, the major influence of a diuretic was confined predominantly to the left ventricular internal diameters rather than wall thickness parameters. We did not observe a decrease of left ventricular internal diameters or left ventricular volumes.

The method of measuring LVM by echocardiography requires some comment. The reproducibility of 2-dimensional and M-mode echocardiography has been validated in our echocardiography laboratory, and variability is in accordance with recently published data on the quality of echocardiographic readings.

Confirming experimental data, a considerable regression of LVH was obtained after 8 months of treatment with the Ang II antagonist valsartan in essential hypertensive patients, indicating that valsartan may safely be given to patients with LVH. The long-term clinical benefit of the LVH reduction obtained after chronic treatment with Ang II antagonists has to be elucidated in clinical studies using end points such as cardiovascular events and mortality.

Appendix

Participating General Practitioners

K. Albrecht, S. Mösch (Unterhaching); E. Bakker (Grundau); F. Criveanu (Frankfurt); A. Faust (Mainz); F. Frohnapfel (Ludwigshafen); G. Härter, V. Rude (Reilingen); V. Janevski (Frankfurt); E. Reichwein (Villmar); R. Santo (Lahnau); A. Schmidt (Offenbach); R. Schneider (Wetzlar); M. Stoll, A. Dietz (Dreieich); R. Will (Frankfurt); W. Oldenburg (Frankfurt), Germany.

Acknowledgments

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Influence of the Angiotensin II Antagonist Valsartan on Left Ventricular Hypertrophy in Patients With Essential Hypertension
Petra A. Thürmann, Peter Kenedi, Andor Schmidt, Sebastian Harder and Norbert Rietbrock

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